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POPULATION AND ECOLOGY OF THE INDIAN FOX *VULPES BENGALENSIS* AT ROLLAPADU WILDLIFE SANCTUARY, ANDHRA PRADESH, INDIA[1]

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(*With six text-figures*)

Key words: Indian fox, *Vulpes bengalensis*, *Ardeotis nigriceps*, population, diet, breeding season, Rollapadu Wildlife Sanctuary, Andhra Pradesh

The population of the Indian fox *Vulpes bengalensis*, its spatial and temporal abundances, den distribution, characteristics and use, predation on eggs and chicks of the great Indian bustard *Ardeotis nigriceps*, and general ecology were studied from February 1993 to April 1995 at the Rollapadu Wildlife Sanctuary (RWS), Andhra Pradesh state, India. The population and spatial abundance of the fox was estimated by enumeration and monitoring of dens, animal sightings at den sites and from censuses.

The population of the fox at RWS was estimated to be around 40-50 adult animals in 1993 and 1994, which declined to about 10 animals in 1995 due to an epidemic. Densities of the fox were significantly higher in the protected grasslands {0.65/40 ha ± 0.99 (S.D)} than unprotected grasslands (0.15/40 ha ± 0.49). A total of 135 dens (active and non-active), comprising of 33 'den groups', were located in the study area. There was a concentration of dens in and around protected grasslands. Den use by the Indian fox at RWS was confined to the pup rearing season (February to June/July). We did not record any evidence of fox predation on bustard eggs and chicks.

Introduction

The Indian fox *Vulpes bengalensis* is a widespread species in India, ranging from the foothills of the Himalayas to Kanyakumari (Prater 1980). In spite of its wide distribution and proximity to human habitation in many areas, it has not been studied adequately (Johnsingh 1978). The population of the Indian fox in Rollapadu Wildlife Sanctuary (RWS), Andhra Pradesh had undergone a remarkable increase after the establishment of the Sanctuary in the early 1980s to protect the great Indian bustard and its habitat (Manakadan and Rahmani 1989, 1993, 1997). The Indian fox is known to be a predator of eggs and probably chicks of the bustard (Rahmani and Manakadan 1987). This was suspected to be one of the reasons for the decreasing numbers of the great Indian bustard at RWS over the years, in spite of good protection to the bird and its habitat. We undertook this study to estimate the population of the Indian fox at RWS; compare its abundance in protected and unprotected sites in the Sanctuary; assess reasons for the differences in abundance between sites (which could explain the increase in

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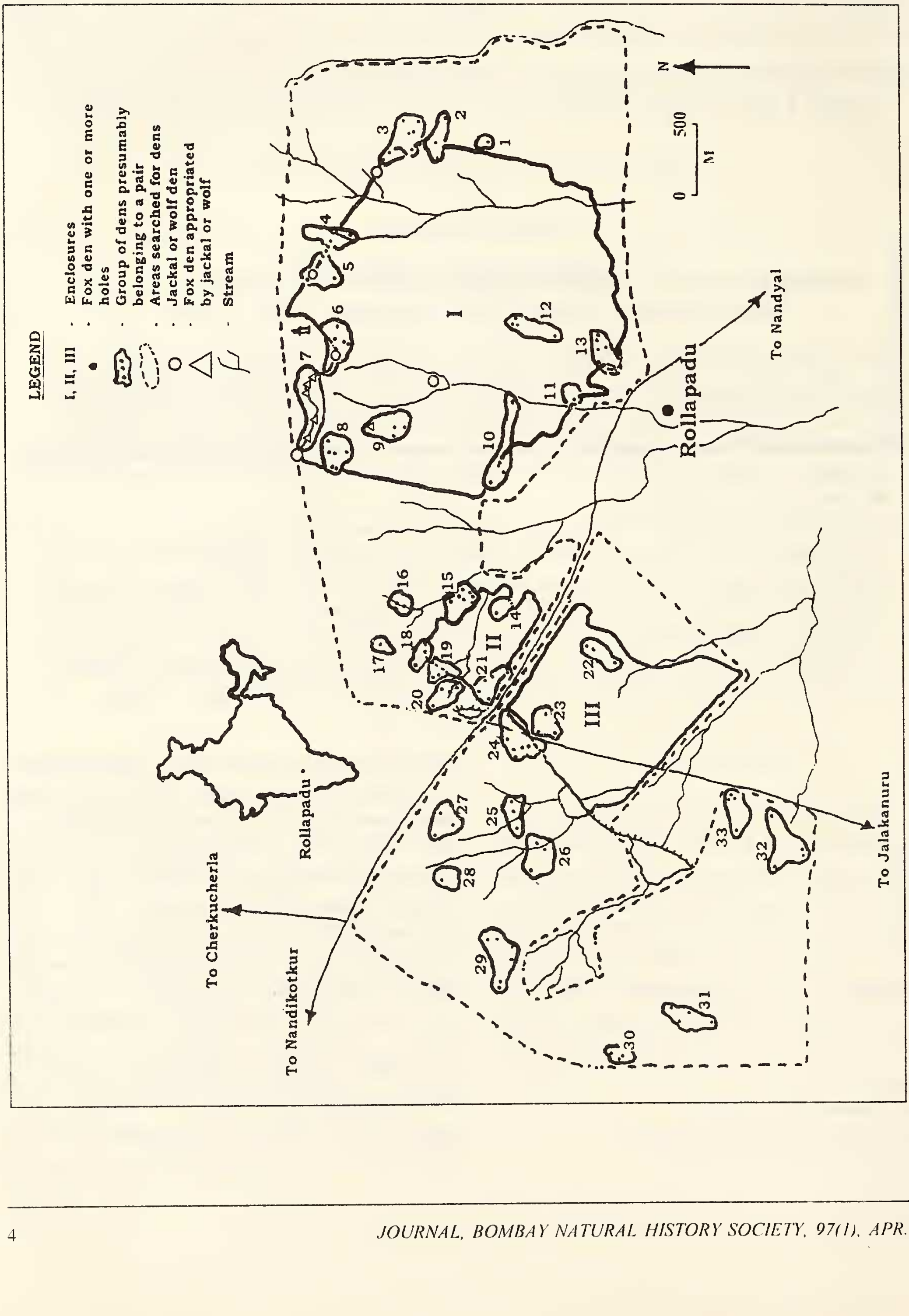

Fig. 1: Location of fox dens in the study area

populations over the years after protection); investigate the role of the fox as a predator of bustard eggs and chicks; and collect other ecological information on the species.

STUDY AREA

Rollapadu is 18 km southeast of Nandikotkur (15°58' N lat. & 78°18' E long.), Kurnool dist., Andhra Pradesh. It lies in the plains between the Nallamalai and Yerramalai hills, at about 200 m above msl. The terrain is gently undulating with predominantly poor red soil. The region is semi-arid with an average annual rainfall of 668 mm, received from both the southwest (June to August) and northeast (September to December) monsoon. Summer (March to May) peaks at 42°C and winter (November to February) is mild at 17° C.

Rollapadu Wildlife Sanctuary (area: 6.14 sq. km) was established in 1982, after the 'rediscovery' of the great Indian bustard *Ardeotis nigriceps*, and was declared a sanctuary in 1988. The sanctuary proper consists primarily of three grassland plots or enclosures: Enclosure-I (320 ha), about 500 m north of Rollapadu, and Enclosure-II (40 ha) and III (120 ha), both about 1.5 km to the northeast of Rollapadu (Fig. 1). These enclosures are demarcated by trench-cum-mound (TCM) walls to exclude livestock and people. However, Enclosure-III was opened to grazing after protests by the locals about the lack of grazing land for their livestock. The extent of protection to Enclosure-II varied from year to year during the study. The three enclosures are separated from each other by grazing lands and crop fields. Both the grazing lands and the enclosures are predominantly grasslands, with scrub dominated areas along streams.

The other major fauna of the Sanctuary include the blackbuck *Antilope cervicapra*, wolf *Canis lupus*, jackal *Canis aureus*, jungle cat *Felis chaus*, common mongoose *Herpestes edwardsi*, blacknaped hare *Lepus nigricollis nigricollis*, common Indian monitor *Varanus bengalensis* and lesser florican *Sypheotides indica*. The grassland is a major roosting ground for harriers (largely *Circus pygargus* and *C. macrourus*) wintering in the Indian subcontinent. For more details, see Rahmani and Manakadan (1986) and Manakadan and Rahmani (1989, 1993 & 1997).

METHODOLOGY

Studies were conducted from February 1993 to April 1995, during daylight hours on unmarked animals. Prior to the studies, we had a fairly good idea of the population and distribution of the fox in RWS from July 1992, due to our field visits during other multi-disciplinary studies of the project.

Population: A pilot survey was conducted during the breeding season in 1993 to assess den distribution in the study area. The survey was concentrated in the three enclosures and grazing lands adjoining them, to get an insight into the breeding season, den characteristics and distribution of the fox in the Sanctuary. Den searches were more intensive during the breeding season of 1994 and 1995. Searches in 1994 began in February, when the dens located in 1993 were found to have been dug up afresh, indicating the start of the breeding (pup rearing) season. The area searched (Fig. 1) was divided into smaller blocks and combed intensively for dens by two or three people. The locations of these dens were plotted on a map (Fig. 1) and details, such as active or non-active, number of holes per den, distances between dens, and site characteristics were recorded. After the survey, all the dens were visited once a week to collect data on den use. Sightings of animals (adults and young) at den sites were recorded. We also looked for indirect signs of animal presence, such as freshly unearthed soil, additional holes dug up, pugmarks, presence of scats and food remains at den sites. Visits were made till June (when the animals abandoned the dens with the onset of the monsoons) in 1994, and till May in 1995 (after the breeding season).

Population estimate: Based on the number of dens located, den use data, and number of adult foxes seen at den sites, a rough estimate of the adult population at RWS was determined. Where animals were never seen at active dens throughout the study period, and especially if the den formed part of a complex of dens (termed den group) as in the majority of cases, we presumed that the den / den group belonged to a pair, as two animals for each den group was the norm in most of the den groups.

Densities in grazing land and enclosures: Four sites of 40 ha each were selected in each of the two habitat types. Except for one site in the grazing land, which was predominantly scrub, all the other sites were grasslands. The sites were thoroughly covered on foot fortnightly — on different days — in the evenings from July 1994 to April 1995. Though the sites were searched on different days, repeated flushing of animals from the same areas suggested that the animals were territorial and that there was no significant movement between sites. Each site was searched in an hour's time, by walking at a steady pace, in an irregular and generally zigzag manner. Some light noise (humming, dragging of feet, tapping with a stick) was made to flush the resting, sleeping or hidden foxes inside dens or among vegetation. Loud noise was avoided as it would alert the animal a good distance away, allowing it to slip away without being detected. On flushing a fox, the direction in which it ran and the place it stopped was observed to avoid duplication of counts. The fox sightings were expressed as number of foxes/40 ha.

Food Availability: Data on the abundance of the known food items of the fox, such as fruits (number of fruiting trees) and grasshoppers in the two habitat types was obtained from other studies carried out during the project. Grasshoppers were sampled by the sweep net sampling method (100 sweeps per site), and was done fortnightly at all four sites in both the habitat types. The density of fruiting trees was enumerated by laying 40 quadrats (size 50 x 50 m) each in both the habitat types, and noting the species of trees or shrubs, their numbers and heights. An index of rodent abundance was obtained by enumeration of burrows along one kilometre transects (with a width of two metres), laid at random in both the habitat types. The transects were done during summer (breeding season of the fox). Fifteen transects each were laid in the enclosure and grazing land during 1994 and 1995. For more details, see Manakadan and Rahmani (1997).

Diet: Scats of fox were collected whenever seen, but mostly during the breeding season, when they were available around den sites. The scats were mixed with warm water, strained and dried. After drying, the remains of animal and plant parts were recorded visually. The percentage composition was not estimated systematically, as the main purpose of the exercise was to look for remains of bustard eggs or chicks.

RESULTS

Dens: The breeding (pup rearing) season of the fox in RWS was determined to be between February to May from 3 years observations. The breeding season was heralded by the re-excavation of old dens or digging of new ones in February. Scats of pups were found around den sites during April and May. Pups were seen around the den sites till the onset of the monsoon, after which the dens were abandoned. Thus, den use by the Indian fox at RWS was largely restricted to the pup rearing period.

Fox dens were recorded in grassland or light scrub habitats — none in dense scrub areas. Dens were dug in the flat ground or in trench cum mound walls (TCM) of the enclosures. Two dens were recorded along the slopes of a stream. The number of holes or openings per den varied from one to as high as 43, but two to seven holes were most common (Figs. 2, 3). All the holes of a den were not used, two to seven active holes per den were most frequent. The frequency of

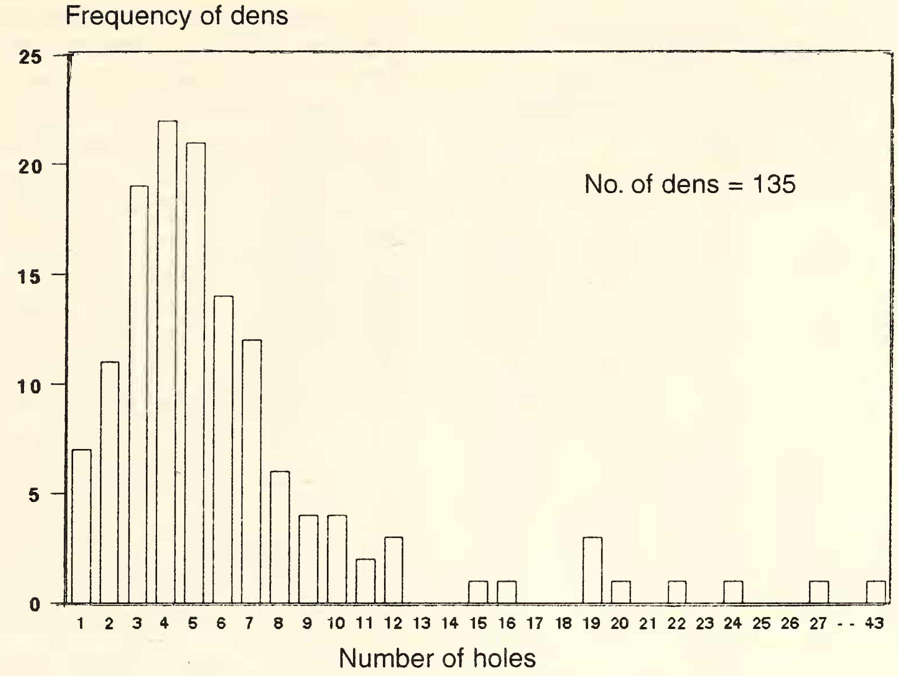

Fig. 2: Number of holes per den

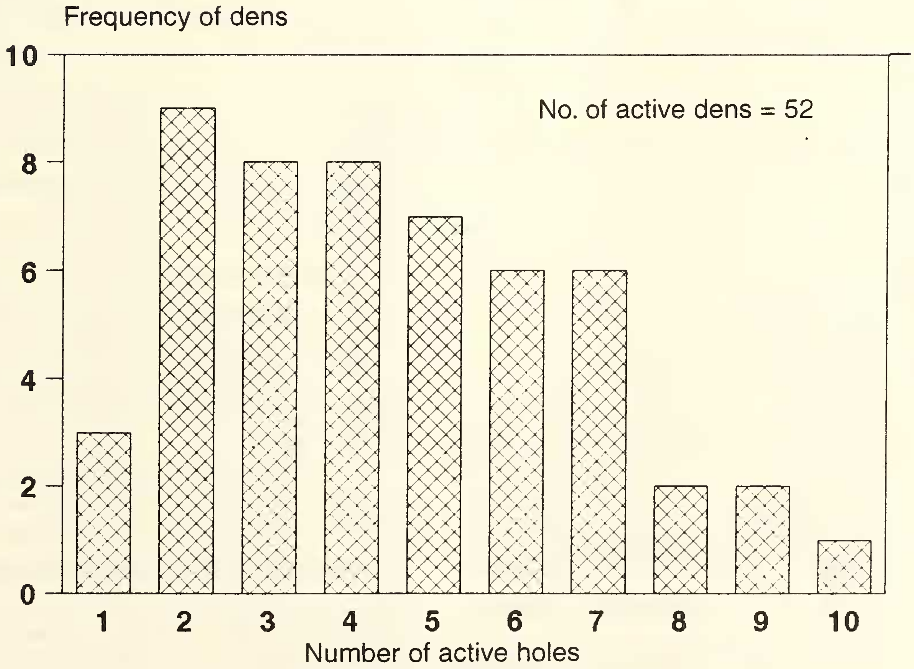

Fig. 3: Number of active holes per den (1994)

TABLE 1
DETAILS AND STATUS OF DEN GROUP
(BASED ON 1994 DATA)

Den Group No.	No. of dens per group	No. of foxes recorded/ estimated	Status in 1994	1993	1995
1	1	0	NA	-	NA
2	4	2*	A	A	A
3	6	2**	LL-A	A	NA
4	5	0	NA	A	NA
5	3	0	O	A	NA
6	5	2*	A	A	NA
7	8	?	NA	A	NA
8	5	2*	A	A	NA
9	5	0	O	NA	NA
10	5	2*	B	A	NA
11	1	0	O	NA	NA
12	4	2**	B	A	NA
13	7	?	A	B	NA
14	2	1*	A	A	NA
15	9	2*	B	B	NA
16	2	0	O	-	NA
17	1	2(?)	LL-A	-	NA
18	2	1*	A	B	NA
19	7	2*	B	A	A
20	4	2**	B	-	NA
21	5	2*	B	A	NA
22	3	0	O	-	NA
23	3	0	O	-	NA
24	8	2**(1*)	A	A	A
25	3	?	LL-NA	-	NA
26	3	2(?)	A	-	NA
27	3	2**	B	-	NA
28	1	1*	A	A	NA
29	5	2**(1*)	A	-	A
30	3	?	A	-	A
31	4	2**(1*)	A	-	B
32	4	2(?)	A	A	NA
33	4	?	LL-NA	B	NA

*	- from sightings
**	- from signs (scats or intensive burrowing)
2**(1*)	- 1 seen, but probably used by a pair.
?	- uncertain
A	- Active burrows regularly used, dug or redug
NA	- Not active, dug early in the season, but later largely or totally unused.
O	- Dens of previous years: not dug at all during the year of survey.
B	- Breeding (pups or scats of pups seen)
LL-A	- Located late (after breeding season); - probably active
LL-NA	- Located late (after breeding season); - probably not active
-	- Not located - all or some of the dens of the den group were not located.

active openings in the eight breeding dens of 1994 were six for three dens, five for two dens, three for two dens and nine for one den.

Many of the dens in the grazing land had rodent burrows around them, indicating that these sites had been appropriated from rodents. In some cases, the rodents continued to live in some of the burrows not enlarged by the fox. Reuse of dens by rodents after the fox had abandoned the dens during the monsoon was recorded in some cases. On two occasions, large monitor lizards *Varanus bengalensis* were recorded entering active fox dens. Once, a large monitor lizard, flushed by us near a den site, ran into a fox den, from which a family of gerbils rushed out and ran into their burrows a few metres from the fox den. Seven of the fox dens were appropriated by jackals or wolves (Fig. 1).

During the preliminary non-intensive searches for dens in 1993, a total of 52 dens were located (33 active and 19 non-active). Breeding activity was detected in 4 dens: 1 in Enclosure-I, 2 in Enclosure-II and 1 in the grazing land. During intensive searches in 1994, a total of 135 dens were located, of which 52 were active. Of the 135 dens, 51 were in Enclosure-I, 15 in Enclosure-II, 9 in Enclosure-III and 60 in the grazing land. As much as 31% of the dens in the grazing land were close to Enclosure-I and II. Breeding activity was recorded in eight dens: three dens each in Enclosure-I and Enclosure-II; one each in Enclosure-III and grazing land. During the breeding season in 1995, no additional dens were located. Of the dens located in 1994, only eight dens were reused (active). Breeding was confirmed at only one den in the grazing land.

From the data on sightings of animals and den use, it was evident that many of the foxes used more than one den. From this data, the 135 dens located during the intensive survey in 1994 were grouped into 33 den groups, of which 22 were active (Table 1 & Fig. 1). Dens of a group generally tended to be clumped in an area, the distances between dens varying from as close as

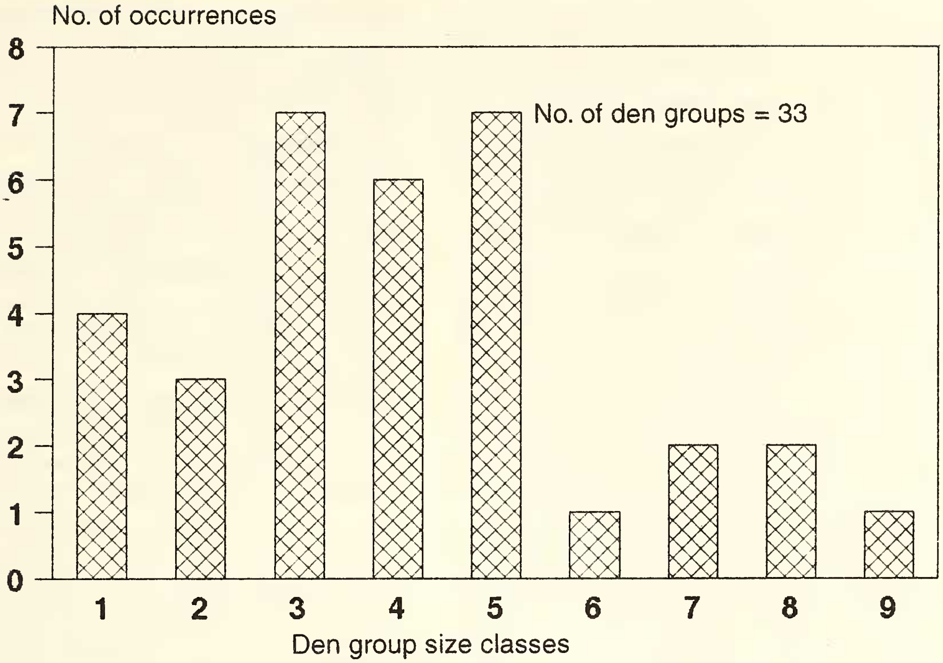

Fig. 4: Number of dens per den group (1994)

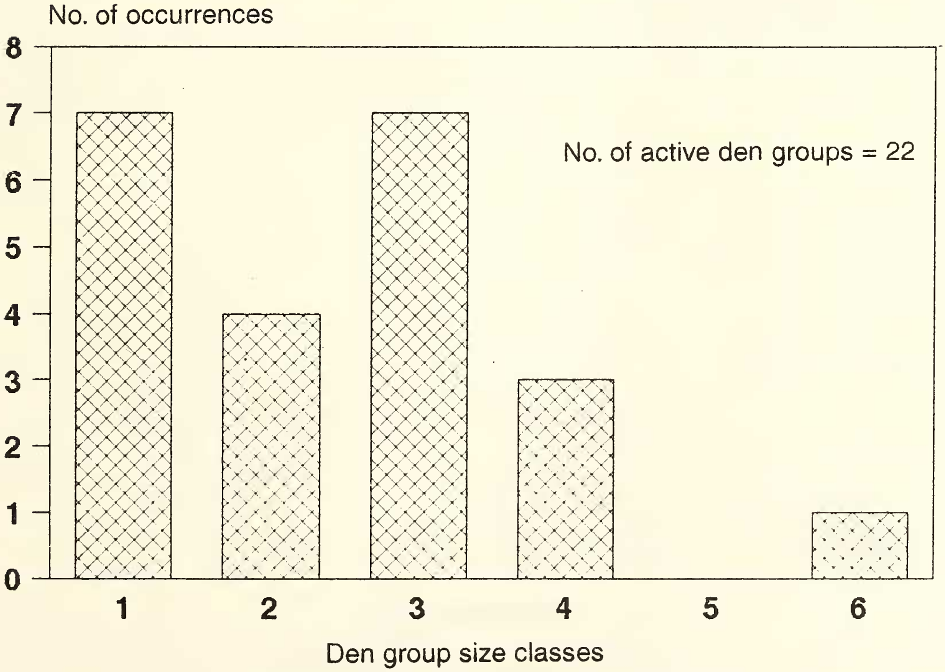

Fig. 5: Number of active dens per den group (1994)

12 m to 100 m. In some cases, the distance of a den from the main cluster was more than 200 m (e.g., den group no. 10 - Fig. 1), but these were clumped to the group, based on sightings and movements of adult and young foxes between dens. In some cases, we grouped two clusters of adjoining dens into one (e.g., den group no. 7), as one of these clusters was hardly used and was probably the denning site of the pair in the area during a previous year. The distances between den groups varied, and were less in the enclosures {Enclosure-I: 463.6 m ±283.8 (S.D.), Enclosure-II: 275.0 m ±302.9, Enclosure-III: (400.0 ±424.3) than the grazing land (633.3 m ±314.3)}. The number of dens per den group varied from one to nine dens, with three to five dens being most frequent (Fig. 4). However, not all dens in a den group were active during a year, one to three active dens was most common (Fig. 5). We presume that each (active) den group belonged to either a pair of foxes or rarely individuals, but cannot be certain as the animals were not collared, the nocturnal movements were not monitored, and a few dens showed all signs of regular use (especially those in the grazing lands), but no animals were sighted in them.

Population: We regularly saw five pairs of foxes around Enclosure-I (den group 3, 6, 8, 10 & 13), four pairs around Enclosure-II (den group 14, 15, 19, 21), three pairs in the grazing lands east of Enclosure-III (den group 25, 31 and 33), and a single individual at den group 28 during our field trips in 1993 and 1994 — a total of 25 foxes. Judging from the number of dens and groups, den use data, and sightings of the animal around dens during the census, it is estimated that about 40-50 foxes were present in the study area during the 1994 breeding season. About the same numbers should have been present during 1993. In 1995, the population dropped to about 10 animals due to an epidemic.

The foxes were usually seen in pairs around the den-groups. Two instances of four adult animals frequenting a common area was

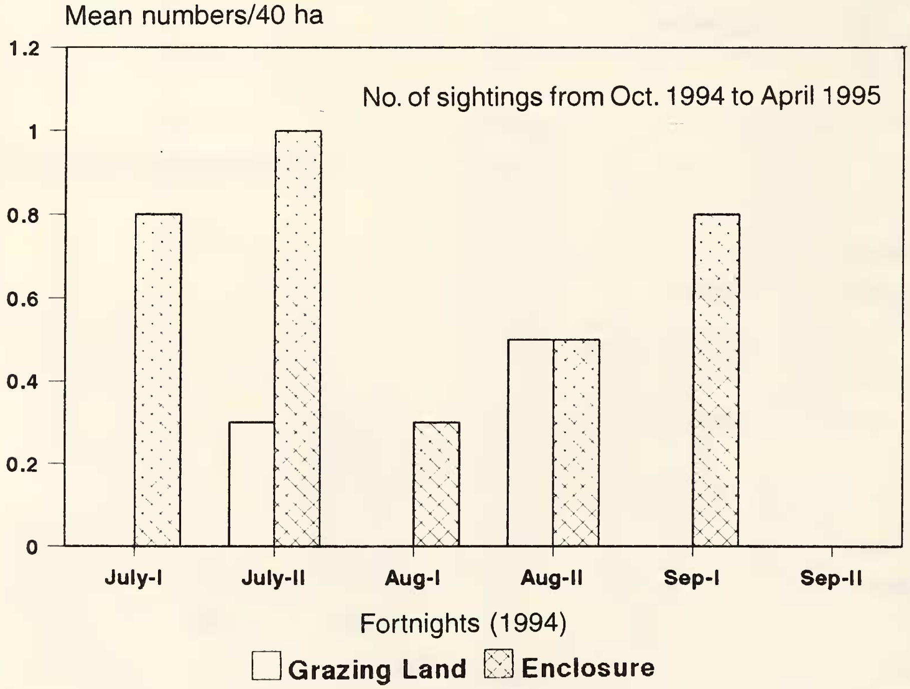

Fig. 6: Abundance (sighting / 40 ha) of the Indian fox in the two habitats

observed. In the first instance, it was during the early monsoon period, when four animals (probably pairs from nearby waterlogged dens) regularly sheltered under a fallen tree as the grass cover was burnt off in a summer fire. In the other instance four adult animals were flushed from a non-breeding den in summer. Otherwise, pairs were the norm and even in clumped den areas, the pairs kept to themselves. Solitary animals were flushed from dens on a few occasions, but the possibility of the mate sleeping elsewhere unnoticed cannot be ruled out. The only den where solitary animals were repeatedly flushed, was at den group 28, which comprised of only one den with a single entrance. Additionally, this was the only single-hole den from which we had actual sightings of the animal.

Abundance of the fox was significantly higher ($U=140$, $P<0.05$) in the enclosure (mean 0.65/40 ha, S.D. ± 0.99) than in the grazing land (mean 0.15/40 ha S.D. ±0.49). The fox was recorded during all the fortnights in the enclosures from the first week of July 1994, till the first week of September 1994 (Fig. 6). In the grazing land, the fox was recorded only during two fortnights between July to August 1994. In both cases, the foxes were close to Enclosure-II, and ran into it on being approached. All the sightings in the grazing land and enclosures were in 'grassland habitats', none in scrubland. After the second week of September 1994, there were only rare sightings of the fox in the Sanctuary. The remains of five foxes and two wolves were found at different places between July to September. The locals too reported seeing dead foxes. After the epidemic, the only sightings were of single animals, one each in Enclosure-II and the grazing land (den group No. 31) during March and April 1995.

Food Availability

Fruits: Of the two species of fruits recorded to be eaten by the fox, the density of *Cassia fistula* was higher in the enclosure (1.8 trees/ha) than in the grazing land (0.2 trees/ha). Though the density of *Zizyphus mauritiana* was about the same in the enclosure and the grazing land, the trees were relatively taller in the enclosure (mean = 1.5 m) than in the grazing land (mean = 0.65 m), and yielded more fruit. Other fruits that could probably be part of the diet of the fox are *Morinda tinctoria* and *Phoenix sylvestris*. Trees of these two species were more abundant in the enclosure (0.6 and 5.2 trees/ha respectively) than in the grazing land (1 tree/ha for *P. sylvestris*; *M. tinctoria* not recorded). The higher densities of fruiting trees and fruit yield, and restrictions on harvesting of fruits in the enclosures, make the availability of fruits greater in the enclosure than grazing land.

Grasshoppers: Insect sampling showed that there was a slightly higher abundance of grasshoppers in the enclosure than in the grazing land. Besides numerical abundance, there was greater insect biomass availability in the enclosure due to the predominance of a larger species of grasshopper (*Acorypha*), compared to a smaller species (*Chrotogonus*) in grazing land. Studies on the great Indian bustard have shown that *Acorypha* is preferred to *Chrotogonus*, especially by adult birds (Manakadan and Rahmani 1990). The fox would also find feeding on the larger species more profitable.

Rodents: Rodent burrows were recorded only in the grazing land in 1994 and 1995. Of the 15 transects each laid in the grazing land for both the years, a total of seventeen burrows (2 active and 15 non active) were recorded in five transects during 1994, and nine burrows (6 active and 3 non-active) were located in 5 transects during 1995.

Diet: Analysis of 58 scats showed the presence of rodents, hare, monitor lizard and grasshoppers (predominantly *Acorypha* sp.) among the animal matter. Among vegetable matter, seeds of groundnut *Arachis hypogea*, *Zizyphus mauritiana* and *Cassia fistula* were recorded. Remains of eggs or chicks of the great Indian bustard were not recorded. Scats of pups were almost solely made up of rodent fur.

Threats: The potential predators of the fox at RWS are the wolf, jackal, jungle cat, monitor lizard (on young), and large raptors. Wolves and jackals were seen digging (to eat cubs?) or appropriating fox dens during the breeding season. Large monitor lizards were also seen entering dens on a few occasions. The remains of two foxes, with the flesh stripped off neatly from the bones, were found, indicating that the kills were made by birds of prey. A local reported seeing a dog killing a fox (during the epidemic), but we observed play between a fox and a half grown dog (at a good distance away from each other). The local people do not eat the fox, but two communities, the *Pardhis* based at Nandikotkur and a nomadic beggar community, hunt and eat them. We recorded three dens that were smoked and dug out in the grazing land. Poachers do not hunt in or near the enclosures, for fear of being caught by the Forest Department.

DISCUSSION

Fox populations often increase steadily with the years, reach levels of overpopulation or saturation, and then decline rapidly due to epidemics (Rausch 1958, Prater 1980, Wandeler *et al.* 1974, Malcolm 1986, and Ginsberg and Macdonald 1990). In RWS, the population of the fox had increased from half a dozen animals during 1985-87 (Manakadan and Rahmani 1987) to about 40-50 animals during 1992-94. It then dropped down to about 10 animals in 1995 due to an epidemic. Canine distemper and rabies are common among canids and could be an important factor in controlling populations, especially of the fox, due to their greater numbers and density (Mech 1970, Wandeler *et al.* 1974 and Malcolm 1986). The increase in population of the fox in the Sanctuary could have been a natural occurrence, or brought about by the protection of the species and its habitat after the establishment of the Sanctuary.

Scrub control is suggested as a management tool to aid detection and avoidance of terrestrial predators of the San Joaquin kit fox *Vulpes macrotis mutica* (Warrick and Cypher 1998) and the desert kit fox *Vulpes macrotis arsipus* (Zoellick *et al.* 1998). Tree and shrub growth at RWS has increased significantly, especially bordering streams (Manakadan and Rahmani 1997), and the fox or its dens were not recorded in such habitats. Scrub control appears necessary in such areas, as it gives cover to potential predators of the fox, such as wolf, jackal and jungle cat, to stalk the species. The fox was recorded in light scrub areas, which appear important for resting and shelter during the day (especially during the non-denning period), and may be vital to the species to escape aerial predators (such as eagles), especially in over-grazed or burnt areas.

Digging of dens in trench cum mound (TCM) walls is easier due to the loose soil and rubble on the trenches, and this may explain the concentration of dens in the enclosures and TCM walls. Most areas of grazing land had shallow soil, exposed rock beds and a calcareous layer, which made digging of dens difficult. In the case of the Arctic fox *Alopex lagopus*, Eberhardt *et al.* (1982) mentioned that den sites were restricted to areas where the permafrost was sufficiently deep and soil characteristics allowed burrowing. It is also likely that absence of poaching results in the concentration of dens in an area. This is because the young have greater chances of survival, and on maturity, some of them dig dens in the vicinity of their parents' dens, especially since foxes are social canids. This may explain the clumped distribution of dens and den groups in the protected enclosures, in contrast to relatively dispersed distribution in the grazing land.

Although TCM walls may attract the fox for denning, it is primarily protection, habitat improvement and lack of disturbance that have attracted them to the enclosures. This explains why dens were concentrated in Enclosure-I and II (protected plots), but not in Enclosure-III (unprotected). Malcolm (1986). and Ginsberg and Macdonald (1990 - quoting various sources) reason that clumping of fox dens is an indication of good habitat. Trottier (1992) mentioned that the swift fox *Vulpes velox* prefers grass of moderate height. This may also be true for the Indian fox, for respite from the heat and protection from aerial predators, especially eagles. The protected enclosures were relatively free of human disturbance. Foxes in the grazing land were frequently disturbed by the movements of people, graziers and dogs. During our visits to the dens, sightings of animals were common around den sites in the enclosures, but were rare in the grazing land. It was not clear whether the foxes in the grazing land come out of their dens only at dusk to avoid frequent disturbance (and were hence missed during our visits), or they took refuge elsewhere during the day.

Multiple den use is likely to be both, a strategy to confuse predators (jackal and wolf) and for sanitation. In the desert kit fox *Vulpes macrotis arsipus*, individuals were reported to use 3-16 dens, while pairs use 9-16 dens (Zoellick *et al.* 1998). Canids are known to move their pups regularly to different dens (Sargeant *et al.* 1975), and this has also been reported in the Indian fox (Johnsingh 1978). Sargeant *et al.* (1975) recorded splitting of litters among two or more dens in the red fox *Vulpes vulpes*. In this study, it was observed that usually after breeding and occupancy of a den for about two months, the pair shifted to another den nearby and even to a third den later on. Half grown pups then frequent all such dens of the den group.

Johnsingh (1978), from his studies in Madurai dist., Tamil Nadu, recorded dens with either two holes or the more common multiple opening dens (maximum of 23 holes). In this study, except for a few single hole dens, the rest were multiple hole dens (up to 43 openings). A greater number of holes per den probably indicates the use of the dens by the same pair for many years, as stated by Johnsingh (1978). However, unlike Johnsingh's findings, areas around dens in RWS had less vegetation compared to the surrounding areas. This is because the soil at RWS has a calcareous layer. This layer when brought to the surface by the foxes digging, hinders plant growth.

The extent of predation on bustard eggs and chicks by the fox was not established. Remains of eggs or chicks were not recorded in the scats analysed, probably because most scats were not collected in the major breeding season of the bustard. It is also unlikely for egg shell pieces to appear in the scats, as the fox might lick the egg contents and leave the shell. In some cases of nest predation recorded during this and the earlier study [predator not known] shell pieces were found strewn around the nest sites. As for chicks, not much identifiable matter could be expected in the scats, except for the bill or claws.

A major drawback of our studies on the Indian fox was that we could not investigate the nocturnal activities of this largely nocturnal species. Also, it was not possible to identify individuals from body characteristics since the animals were not marked. A study of radio-collared animals with the help of night vision equipment is essential to get precise information on the species.

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